

PAZHASTL.CLS 08.02.06

## XSS J00564+4548 AND IGR J00234+6141 — NEW CATAclysmic VARIABLES FROM *RXTE* AND *INTEGRAL* ALL SKY SURVEYS

© 2008 I. F. Bikmaev<sup>\*1,2</sup>, M. G. Revnivitsev<sup>3,4</sup>, R. A. Burenin<sup>3</sup>, R. A. Sunyaev<sup>3,4</sup>

<sup>1</sup>Kazan State University, ul. Kremlevskaya 18, Kazan, Russia

<sup>2</sup>Academy of Sciences of Tatarstan, ul. Baumana, 20, Kazan, Russia

<sup>3</sup>Space Research Institute (IKI), ul. Profsoyuznaya 84/32, Moscow, Russia

<sup>4</sup>Max-Planck-Institut für Astrophysik, Garching, Germany

Received February 5, 2008

We present the results of optical identification of two X-ray sources from *RXTE* and *INTEGRAL* all sky surveys: XSS J00564+4548 and IGR J00234+6141. Using the optical data from Russian-Turkish 1.5-m Telescope (RTT150) and *SWIFT* X-ray observations, we show that these sources most probably are intermediate polars, i.e. binary systems with accreting white dwarfs with not very strong magnetic field ( $\lesssim 10$  MG). Periodical oscillations of optical emission with periods  $\approx 480$  and  $\approx 570$  s were found. We argue that these periods most probably correspond to the rotating periods of the white dwarfs in these systems. Further optical observations scheduled at RTT150 will allow to study the parameters of these systems in more detail.

**Keywords:** cataclysmic variables — X-ray sources — optical observations

### INTRODUCTION

The most information on the population of low-luminous X-ray binaries comes from *ROSAT* All Sky Survey (RASS, Voges et al., 1999). The X-ray luminosities of these low-luminous binaries are  $\sim 10^{30-33}$  erg/s which corresponds to distances up to only one kpc in RASS and therefore are not concentrated to Galactic disk. Deeper *ROSAT*, *Chandra* and *XMM-Newton* pointings can not provide more data because fainter objects can only be found in Galactic plane where their surveyed volume is much smaller and observations are hampered by Galactic absorption and large number of faint galactic stars. Nearby objects are also more interesting because they are bright and can be studied in more detail.

Unfortunately, for observations of some classes of X-ray sources RASS energy band (0.2–2.4 keV) is far not optimal. For example, spectra of accreting white dwarfs with  $\sim 10^6$  G magnetic fields frequently have significant intrinsic photoabsorption because of matter falling to their polar caps. Soft X-ray emission ( $< 2$  keV) of these white dwarfs can be strongly suppressed compared to harder X-ray emission ( $> 3$  keV).

The most sensitive all-sky X-ray survey completed to date in this harder energy band is *RXTE* Slew Survey (XSS, Revnivitsev et al., 2004). This survey contains useful information on the population of low-luminous X-ray binaries. The numbers of these systems in XSS and RASS are actually comparable, in spite of very different total number of X-ray sources detected in these surveys. For example, the total

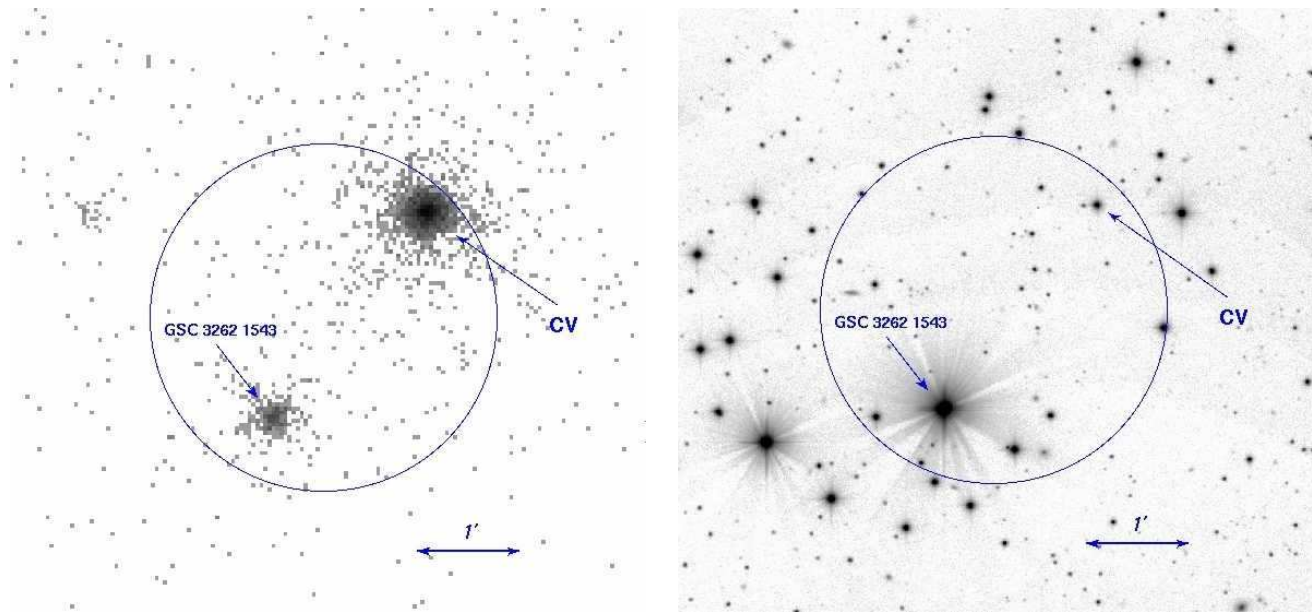
number of known intermediate polars is 44 (Ritter & Kolb, 2003), while the number of these objects among identified XSS sources is 13 (Revnivitsev et al., 2004; Sazonov et al., 2005). The reason is that the main part of objects identified with bright stars in RASS are chromospherically active stars with much softer X-ray spectrum which are not detected in XSS.

Due to poor angular resolution of XSS the nature of 18 XSS sources (out of 294) remains unknown. According to general characteristics of unidentified XSS objects, the most of them should be nearby active galactic nuclei (AGNs), but there should be also Galactic binary systems, most of them — accreting white dwarfs (Revnivitsev et al., 2004).

The total number of known accreting white dwarfs is not large (e.g., Ritter & Kolb, 2003) and discovery of any subsample of these objects gives useful information to study of population of white dwarfs in Galaxy. Even more useful is to study accreting white dwarfs in statistically definite survey. This allow to directly calculate volume density of these objects and their contribution to Galactic X-ray emission (see e.g., Sazonov et al., 2005). This is why the identifications of the sources discovered in *RXTE* and *INTEGRAL* all-sky surveys are very important.

In 2005 we initiated a program of optical identifications of X-ray sources from *RXTE* and *INTEGRAL* all-sky surveys. In frames of this program we already identified six objects as previously unknown nearby AGNs (Bikmaev et al., 2006). In this paper we show that according to the results of observations of *SWIFT* XRT in X-rays

\*e-mail: ilfan.bikmaev@ksu.ru



**Fig. 1.** The X-ray and optical images of the XSS J00564+4548 field. Left — *SWIFT*/XRT X-ray image, the error circle of *ROSAT* source is also shown. Right — RTT150 optical R-band image. In both images North is up and East is left, scale is similar and shown in the images.

and Russian-Turkish 1.5-m Telescope (RTT150) in optical, sources XSS J00564+4548 and IGR J00234+6141 are binary systems with accreting white dwarfs, most probably intermediate polars.

### OBSERVATIONS

Optical data were obtained using two instruments at RTT150 telescope — CCD-photometer and spectrometer TFOSC. Short description of these instruments and methods of data reduction, used in our work on optical identifications of *RXTE* and *INTEGRAL* objects, are given in Bikmaev *et al.* (2006).

#### *XSS J00564+4548*

The object XSS J00564+4548 was found in *RXTE* all sky survey and identified with X-ray *ROSAT* source 1RXS J005528.0+461143 detected in RASS. The accuracy of X-ray localization for this X-ray source ( $\approx 40''$ ) is insufficient to identify this source with one of the optical sources in this field.

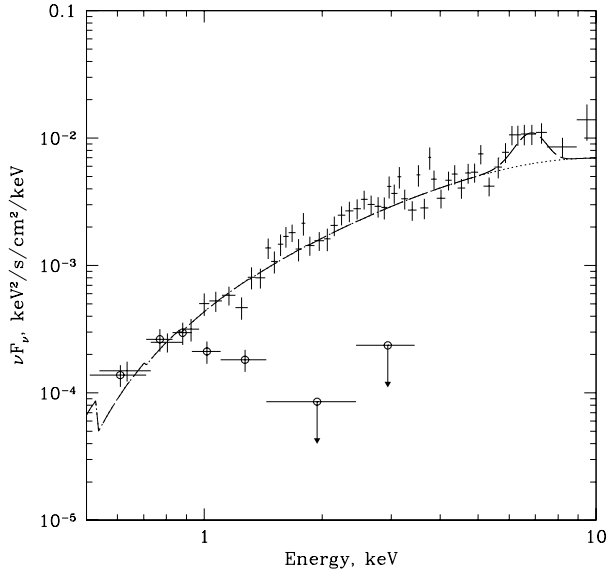
During May – October 2005 time period XRT telescope aboard *SWIFT* observatory (Gehrels *et al.*, 2004) made four observations of this source. In result of these observations it was found that there are actually two X-ray sources in this field which were not resolved by *ROSAT*, each of them giving comparable contribution into *ROSAT* source flux. The X-ray and optical images of this field are shown in Fig. 1 and X-ray spectra of these two sources are shown in Fig. 2. One of the sources is associated with star GSC 3262 1543,  $V \approx 11^m$ . Its X-ray spectrum resemble that of late spectral class star with chromospheric activity or binary system of RS CVn type (see e.g., Schmitt *et al.*, 1990). This source is

soft and could not be detected in XSS, while second X-ray source is much harder (see Fig. 2). Therefore, we conclude that XSS J00564+4548 should be identified with that second *SWIFT* X-ray source and with optical object at coordinates  $\alpha = 00^h55^m20^s.0$ ,  $\delta = +46^\circ12'57''$  (J2000).

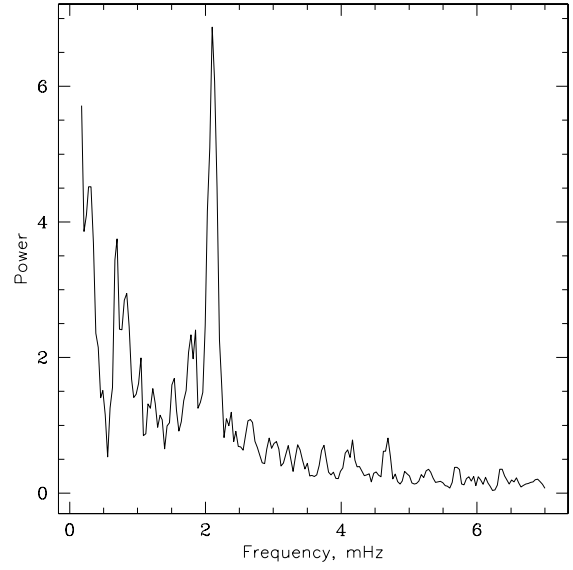
The X-ray spectrum of this source can be adequately described by a simple power law with photoabsorption with photon index  $\Gamma \sim 0.8 \pm 0.1$  and photoabsorption parameter  $N_H L = (0.22 \pm 0.05) \times 10^{22} \text{ cm}^{-2}$ . Galactic extinction from radio 21 cm data is  $0.11 \times 10^{22} \text{ cm}^{-2}$  (Dickey & Lockman, 1990), i.e. somewhat smaller than that seen in X-ray spectrum, which might indicate the presense of intrinsic photoabsorption in the source emission. Photon index is not typical for extragalactic objects (AGNs), which can be expected on that high Galactic latitude, while is very similar to typical photon indexes of accreting white dwarfs — cataclysmic variables (CV).

At the detection threshold in this spectrum there is also a wide emission line near  $\approx 6.7 \text{ keV}$ , which is also typical for CVs and not typical for AGNs. The line is detected with  $\Delta\chi^2$  corresponding to 99.9% probability that this feature is not accidental deviations of the measured points from the power law fit. The equivalent width of this wide line is  $EW = 1.06 \pm 0.30 \text{ keV}$  which is also expected for optically thin plasma emission from accreting white dwarf.

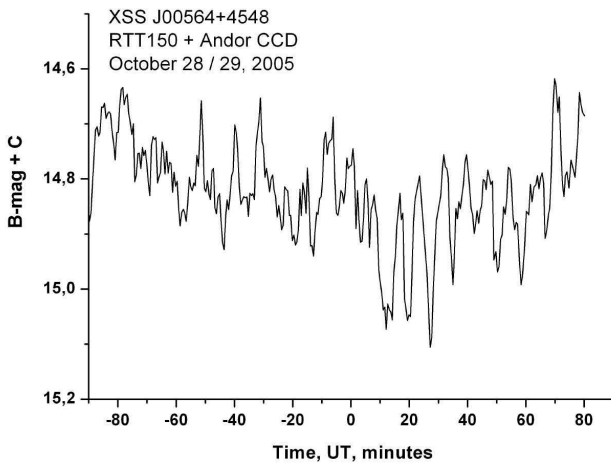
In order to check the hypothesis on the nature of object XSS J00564+4548, we made a set of optical photometrical observations on Aug. 18, 20, Sep. 11 and Oct. 19, 20, 21, 22, 23, 26 and 28 2005. In Fig. 3 the light curve of the optical source obtained on Oct. 28 is shown as an example. We detected strong variability of the optical source with amplitude  $\Delta B \approx 0.3$  on the time scales down to  $\sim 50$ – $100 \text{ s}$ , which com-



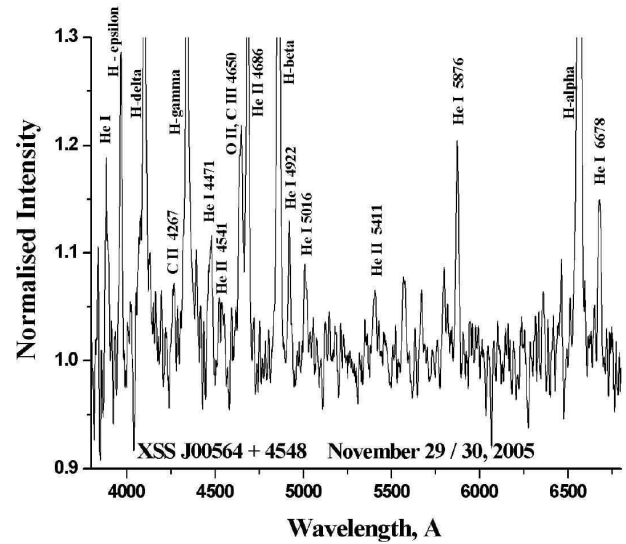
**Fig. 2.** Spectra of two X-ray sources found by *SWIFT*/XRT in the error circle of *ROSAT* source. The spectrum of star GSC 3262 1543 is shown with open circles, CV spectrum is shown with crosses.



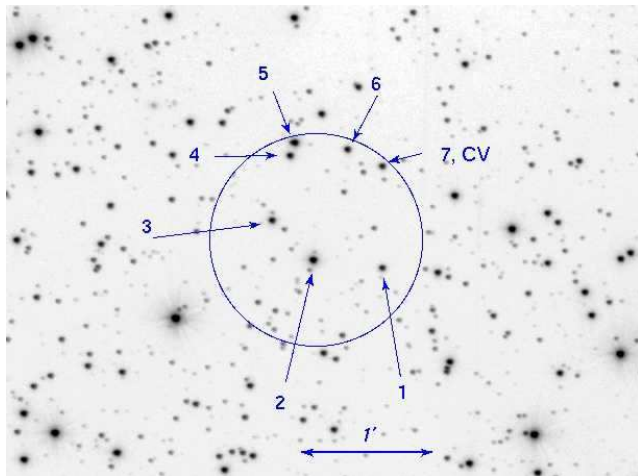
**Fig. 4.** Power spectrum of optical variability of XSS J00564+4548. The prominent peak on  $(480 \text{ s})^{-1}$  is clearly seen.



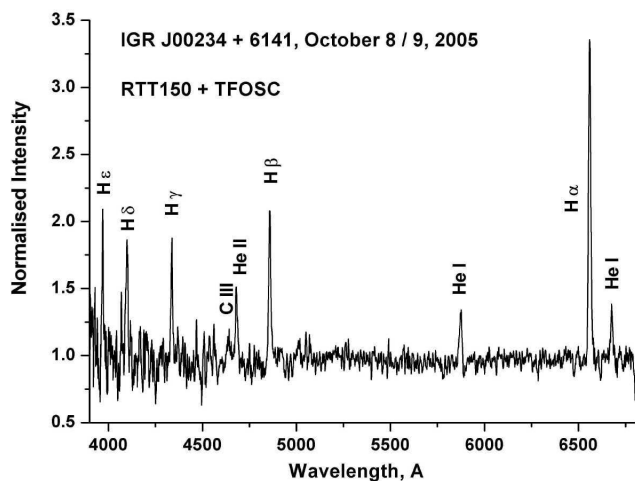
**Fig. 3.** XSS J00564+4548 light curve obtained with RTT150 on Oct. 28 2005.



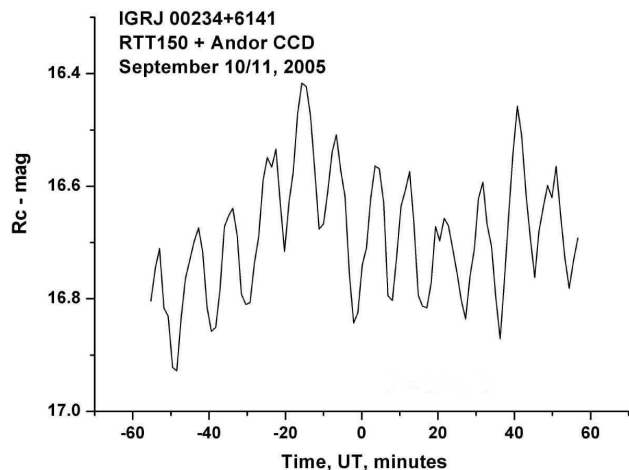
**Fig. 5.** Optical spectrum of XSS J00564+4548, obtained with RTT150 on 29 Nov. 2005.



**Fig. 6.** Optical image of the field of IGR J00234+6141. The numbers show sources for which optical spectra were obtained. Orientation is North-up, East-left, scale is shown in the image.



**Fig. 7.** Optical spectrum of IGR J00234+6141, obtained with RTT150 on Oct. 8 2005.



**Fig. 8.** The optical light curve of IGR J00234+6141 in  $R_c$ , obtained with RTT150 on Sep. 10 2005.

pletely exclude a possibility that this source may be an AGN. A subsequent analysis showed that this variability contains very significant periodic component. In Fig. 4 we show a Lomb-Scargle periodogram (Lomb, 1976) averaged over all available data. The prominent peak on  $(\approx 480 \text{ s})^{-1}$  is clearly seen in this figure. The measured period is most probably not an orbital period of binary system, which is typically an order of magnitude longer, but a rotation period of white dwarf.

We emphasize, that we have no direct information that the period of optical variability is correspondent to just the rotation period of white dwarf and not to the orbital period of this system. However, there are only few CV with orbital periods  $< 1$  hour are known to date (Ritter & Kolb, 2003). The most of them are AM CVn type variables — systems with no hydrogen lines in their optical spectra, since in these systems the accreting matter comes from a degenerate star. Optical spectrum obtained with RTT150 telescope is shown in Fig. 5. The spectrum show bright emission lines, including hydrogen ones, typical for accreting white dwarfs (see e.g., Williams & Ferguson, 1982; Schmidt, Stockman, & Grandi, 1986). Therefore, in this system the accretion should most probably be from a normal star. These systems usually have orbital periods of order of few hours (Ritter & Kolb, 2003).

The magnetic field of white dwarf in this system should be strong enough in order to create asymmetry in the accretion flow, which we see as pulsations. On the other hand its magnitude should not be larger than  $\sim 10$  MG, because in this case the magnetic field of the white dwarf can lock on the secondary star and will synchronize the orbital and white dwarf rotational periods (see e.g. Patterson, 1994). Therefore, on the basis of optical and X-ray data we can classify this object as intermediate polar, i.e. accreting white dwarf with not very strong magnetic field ( $\lesssim 10$  MG).

#### IGR J00234+6141

X-ray source IGR J00234+6141 was discovered in a deep *INTEGRAL* observations of supernova remnant Cas A (Den Hartog *et al.*, 2005). The position of the source (accuracy  $\approx 3'$ ) is consistent with *ROSAT* source 1RXS J002258.3+61411 with much better localization ( $\approx 10''$ ). This good localization accuracy allowed to search the optical companion of this source between only few optical objects.

In Oct. 2005 we obtained spectra of seven most bright optical objects in *ROSAT* error circle. The finding chart of the XSS J00564+4548 field is shown in Fig. 6. The spectrum of seventh object showed strong emission lines with zero redshift, which is the evidence that this is the Galactic object. The spectrum of this source is shown in Fig. 7. A set of emission lines is very typical for cataclysmic variables — accreting white dwarfs (see e.g., Williams & Ferguson, 1982; Schmidt, Stockman, & Grandi, 1986). The X-ray ray source IGR J00234+6141 should be identified with this CV,

since the probability of chance finding of any CV in *ROSAT* error circle is negligible. The coordinates of this object are  $\alpha = 00^h22^m57^s.6$ ,  $\delta = +61^\circ41'08''$  (J2000).

In Jan. 2006 this object was independently observed by other group (Halpern & Mirabal, 2006). From their obtained optical spectrum these authors are also found that this object is a CV and that X-ray source IGR J00234+6141 should identified with it.

Optical photometric light curves obtained on Sep. 10 2005 showed the presence of prominent periodicity with period 570 s. A part of the light curve is shown in Fig. 8 as an example. Periodical oscillations are easily seen in this light curve even with naked eye. Like in case of XSS J00564+4548 (see above), due to small value of measured optical period we propose that if correspond to the rotation period of white dwarf. Therefore, like in previous case, we can classify this object as an accreting weakly magnetized white dwarf — intermediate polar.

### CONCLUSIONS

Using observations of RTT150 in optical and *SWIFT* observatory in X-rays, we identified two *RXTE* and *INTEGRAL* X-ray sources from their all-sky surveys XSS J00564+4548 and IGR J00234+6141. Obtained photometric light curves and optical spectra propose that these objects most probably are accreting binary systems with magnetized white dwarfs — intermediate polars.

Authors are grateful to Hans Ritter and anonymous referees for valuable comments. Authors are also grateful to the director of TÜBİTAK National observatory (Turkey) Prof. Zeki Aslan for his strong support of this work, to A. Galeev, R. Zhuckov (KGU), D. Denisenko and A. Mescheryakov (IKI) for their help in performing optical observations. This work was supported by grants RFFI 05-02-17744, RFFI 05-02-16540, NSH-1789-2003.2 and NSH-1100.2006.2, and also by program of Presidium of the Russian Academy of Sciences “Formation and evolution of stars and galaxies”, and by DFG Priority Programme 1177 “Witnesses of Cosmic History: Formation and evolution of galaxies, black holes, and their environment”. RB also acknowledge support by grant of President of RF, MK-4064.2005.2.

### REFERENCES

- I. F. Bikmaev, R. A. Sunyaev, M. G. Revnivtsev, R. A. Burenin*, Pis'ma v Astron. Zhurn. **32**, 250 (2006); astro-ph/0511405.
- J. P. Halpern, N. Mirabal*, ATEL # 709 (2006).
- P. R. Den Hartog, L. Kuiper, W. Hermsen, J. Vink, J. J. M. In't Zand, R. H. D. Corbet, R. Remillard*, ATEL # 394 (2005).
- J. M. Dickey, F. J. Lockman*, Ann. Rev. of Astron. and Astrophys. **28**, 215 (1990).
- N. Gehrels, G. Chincarini, P. Giommi, K. O. Mason, J. A. Nousek, A. A. Wells*, Astrophys. J. **611**, 1005 (2004).
- N. R. Lomb*, Ap&SS **39**, 447 (1976).
- J. Patterson*, PASP **106**, 209 (1994).
- M. Revnivtsev, S. Sazonov, K. Jahoda, M. Gilfanov*, Astron. Astrophys. **418**, 927 (2004).
- H. Ritter, U. Kolb*, Astron. Astrophys. **404**, 301 (2003).
- S. Sazonov, M. Revnivtsev, M. Gilfanov, E. Churazov, R. Sunyaev*, Astron. Astrophys., in press; astro-ph/0510049.
- G. D. Schmidt, H. S. Stockman, S. A. Grandi*, Astrophys. J. **300**, 804 (1986).
- J. H. M. M. Schmitt, A. Collura, S. Sciortino, G. S. Vaiana, F. R. Harnden, R. Rosner*, Astrophys. J. **365**, 704 (1990).
- W. Voges, B. Aschenbach, Th. Boller, et al.*, Astron. Astrophys. **349**, 389 (1999).
- R. E. Williams, D. H. Ferguson*, Astrophys. J. **257**, 672 (1982).